

## EP-1132

## Geometrical calibration of a Monte Carlo simulated linear accelerator

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**Purpose/Objective:** Standard dose calculation algorithms are imprecise in some situations, especially if tissues with different density are taken into account. The most accurate result is achieved by MC-Algorithms. However due to its required computing resources, it is normally not available in commercial treatment planning systems. The goal of this work is to achieve a customized geometrical model of our linear accelerator to ensure a high accuracy in the dose deposition calculation. This geometrical calibration is necessary due to the rounded MLCs (1).

(1) Philip Vial, Lyn Oliver, Peter B Greer, Clive Baldock (2006) An experimental investigation into the radiation field offset of a dynamic multileaf collimator, Physics in medicine and biology 51 (21) p. 5517-38.

**Materials and Methods:** The chosen MC Code is GEANT4 (2), due to its flexibility with primary particles and geometry modelling. From target to collimators, the clinical accelerator 'Precise' (Elekta) available in our clinic is modelled in close collaboration with the manufacturer. Different profiles were measured with an ionization chamber in a water phantom and the same geometries simulated. According to manufacturer specifications, measurements of the fields were done with the isocenter placed at the maximum of the PDD. The calibration was done for the photon energy of 6 MeV and individual calibration functions were estimated for both leafbanks, backup collimators and X-collimators.

**Results:** Firstly we represented the difference between measured and simulated distance to central axis (DTCA) of each leaf bank or collimator to analyse which type of function is needed to calibrate the corresponding position. As conclusion, a second grad polynomial is a good choice (Figure 1). With the estimated parameters we simulated new fields, and calculated the DTCA for the left-right profile (Y-backup collimator and MLC together) (Table 1). We also used the Gamma Index Criteria from Low in one dimension (3mm/3%) to compare normalized simulated and measured dose profiles. The agreement was above 95%.

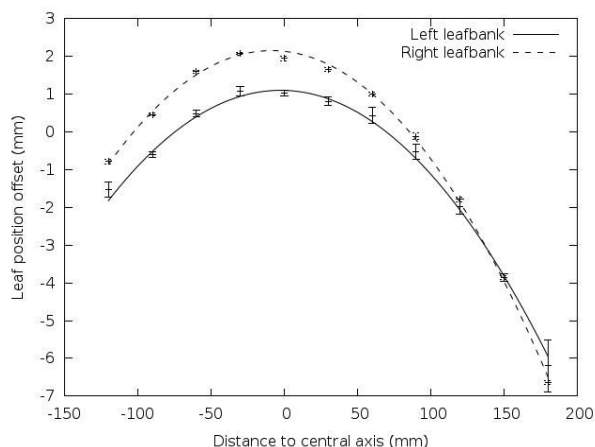


Figure 1.- Difference between measured and simulated DTCA of both leafbanks

DTCA (mm)-Left		DTCA (mm) - Right	
Measurement	Simulation	Measurement	Simulation
29.55 ± 0.19	29.43 ± 0.05	28.49 ± 0.02	28.47 ± 0.05
49.5 ± 0.2	49.50 ± 0.08	48.51 ± 0.03	48.54 ± 0.08
69.4 ± 0.2	69.48 ± 0.06	68.67 ± 0.02	68.62 ± 0.07
99.5 ± 0.2	99.52 ± 0.08	98.78 ± 0.02	98.91 ± 0.06

Table 1.- Measured and simulated DTCA of right and left collimators

**Conclusions:** The simulation is validated with dose measurements, and also with the DTCA determination. We have a model of our lineal accelerator in Geant4 which ensures us not only high accuracy in dose deposition but also in geometrical setup. This precision is required to do 4D simulations, which is the objective of this project.

## EP-1133

## The energy dependency of radiophotoluminescent dosimeters for electron beams

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**Purpose/Objective:** Radiophotoluminescence (RPL) dosimetry with silver-activated-metaphosphate glass dosimeters has been used for six decades in environmental and personal dosimetry. In some extent RPL dosimetry has also been used for in-vivo photon dosimetry in radiotherapy. The purpose of this study was to measure the energy dependency of a commercially available RPL-system (Asahi Techno Glass Corporation/ATG, Shizuoka, Japan) in high-energy electron beams. Before this study there have been only a few short experiments published using RPL for electron dosimetry.

**Materials and Methods:** The RPL-system includes glass rod dosimeters GD-302M and an automatic UV-laser reader FGD-1000. All measurements were performed in a water phantom with a digitally controlled positioning frame (PTW, Freiburg, Germany). Each dosimeter was put into the other end of a thin water filled plastic straw that was attached to the positioning frame from the other end to allow some distance between the dosimeter and the metallic frame. Small pieces of bolus material were used to stop the dosimeter from moving along the straw. The highest available electron beam energy (Varian Clinac iX, 20 MeV, VMS, Palo Alto, USA) was chosen to cover as wide range of energies as possible. The dosimeters were irradiated one by one at the central axis of a 20 x 20 cm<sup>2</sup> field at SSD 100 cm at various depths to 2.0 Gy and each measurement was repeated four times. In addition, 0.1 Gy, 0.5 Gy and 1.0 Gy doses were irradiated to measure linearity. Mean energy at surface of the phantom was calculated as defined in the IAEA TRS-398 code of practise and the mean electron energies at measurement depths were determined according to published Monte Carlo calculated data. Linear regression was used to model RPL reading versus energy.

**Results:** The coefficient of determination (R<sup>2</sup>) for the linear regression to doses from 0.1 Gy to 2.0 Gy was 0.9996. The reading of the RPL dosimeter decreases as the depth increases i.e. as the mean energy decreases (Figure 1). The overall change over the range of electron energies investigated in this work is approximately 9% and we propose that it can be estimated with a linear energy correction of 0.5% MeV<sup>-1</sup>. The R<sup>2</sup> was 0.49 for the linear regression to the readings at different energies which we accept considering that the general uniformity for RPL dosimeters is around 1-2%.

**Conclusions:** We conclude that RPL dosimeter is linear in electron beams as well as in photon beams and to achieve best accuracy over the entire clinical electron energy range an energy correction of 0.5% MeV<sup>-1</sup> is recommended, i.e. an energy correction factor from 1.056 at E<sub>d</sub> = 2 MeV to 0.971 at E<sub>d</sub> = E<sub>0</sub> = 19.6 MeV.

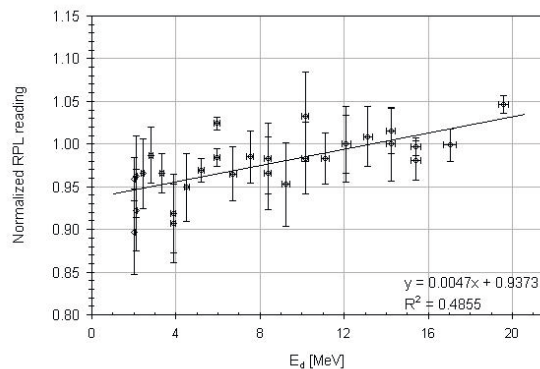


Figure 1 The normalized RPL reading versus calculated mean energy at measurement depth.

#### EP-1134

##### Performance assessment of the Sun Nuclear DailyQA3 Beam Constancy Instrument.

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**Purpose/Objective:** To assess the behaviour of the Sun Nuclear Corporation 'Daily QA3' (DQA3) device, and its suitability for indicating changes in linac beam characteristics.

**Materials and Methods:** The DQA3 is a beam constancy device which uses nine ion chambers at an effective depth of 1.0 g/cm<sup>2</sup> to assess dose output, beam symmetry and flatness in a 20cm x 20cm field. A further four chambers, situated at various effective depths, are used to assess electron beam energy via a complex algorithm. Three diodes on each field edge are used to assess field size. All parameters are reported as relative changes against baseline values. An assessment of the DQA3 was carried out on an Elekta Precise linac, providing photon energies of 6 and 10 MV, and six electron energies in the range 4 - 15 MeV. The stability of the DQA3 dose parameter was determined with reference to independent dosimeter systems. These data were analysed for monthly measurements over a three year period on three linacs. The effect of the shallow depth of the detectors on the reported parameters was studied, with particular reference to the scalability of tolerance limits for relative variations compared to measurements made at standard reference depths. This was achieved by introducing beam profile anomalies which had been previously quantified using a scanning water phantom system (Blue Phantom, IBA Dosimetry).

**Results:** The dose response was found to be stable to within  $\pm 1.0\%$  over three-year analysis period, and across all energies assessed. The instrument was found to reliably indicate relative changes in beam symmetry and flatness. The sensitivity of the reported electron energy parameter was found to be asymmetric around the baseline value. Minor inconsistencies in values reported by the device were discussed with the manufacturer leading to further software improvements (e.g. the implementation of asymmetric tolerance criteria). These have been beta-tested and full release is awaited.

**Conclusions:** The DQA3 was shown to be a reliable instrument for rapidly confirming the stability of linac radiation beams. It was able to detect changes in electron energy, although the tolerances associated with each linac electron energy required careful assessment to be meaningful. The DQA3's performance allowed a scheme to be developed in which the instrument is used weekly as one component of a hierarchical system of redundant instrumentation to improve linac QC efficiency whilst providing a high degree of reassurance.

#### EP-1135

##### Evaluation of dosimetric accuracy of stereotactic radiotherapy with new radiochromic EBT3 film

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**Purpose/Objective:** Aim of this study is to examine the feasibility and dosimetric accuracy of using the new Gafchromic EBT3 model radiochromic film for stereotactic radiotherapy (SRT) quality assurance (QA).

**Materials and Methods:** Measurements were performed using Gafchromic EBT3 films in conjunction with an Epson Expression 10000XL scanner. Uniformity and reproducibility were investigated

analysing five different whole (8'x10') unexposed films (five times each). All scans were performed based on information by the manufacturer as well as published studies: transmission mode, 150 dpi resolution, RGB tagged image file format and acquiring the whole plate area. The images were then processed using the red channel and dividing each whole film in 1 cm wide profiles in both landscape and portrait direction. The pixel values variations across these profiles were analysed to identify the region of the scanner plate with the higher uniformity (to appropriately position patient QA dose distribution films). Uniformity and sensibility dose dependence was also investigated irradiating 4x4 cm<sup>2</sup> films with doses ranging from 1 to 8 Gy (e.g. 0.8 Gy, 1.0 Gy, 1.2 Gy, 2.0 Gy, 2.2 Gy etc.). For each film, ADC values were extracted and evaluated from 2x2 cm<sup>2</sup> areas.

**Results:** For unexposed films, uniformity tested for 1 cm wide profiles across the landscape direction had an average value of 0.58% (2σ values ranging from 0.50% to 0.83%, with the higher value further from the scanner center). Higher nonuniformity in the portrait direction is reported in literature and our results showed an average value of 0.9%. These results did not appreciably vary for the irradiated films. Sensibility of the irradiated films was found to correspond to a few cGy for doses up to ~6 Gy and decreasing for doses from 7 to 8 Gy.

**Conclusions:** This study evaluates the response of the new Gafchromic EBT3 film for typical SRT resolution and doses. The results showed an adequate level of accuracy for all the analysed dose levels, thus verifying the feasibility of using EBT3 films for SRT QA. Sensibility was found to be higher in low dose regions.

#### EP-1136

##### Angular dependence of IN-VIVO bladder detector readings in Ir-192 brachytherapy treatment.

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**Purpose/Objective:** Introducing into clinical practice IN-VIVO dosimetry for bladder raised the need to measure IN-VIVO bladder detector response as a function of the angle to the direction of radiation coming from the Ir-192 radiation source.

**Materials and Methods:** Measurements were done for bladder Single Detector Probe PTW-Freiburg Type T9113-01002. For calibration we used special calibration setup based on Afterloading Calibration phantom for IN-VIVO calibration PTW T 9193 (selected direction of radiation is perpendicular to the source axis and the distance between source and detector is 8 cm). Measurement circle was performed by most accurate method, when the source was sent to calibration position (centre of phantom) only ones, and rotation of the positioned into adaptor detector was realized by remotely controlled motor. For determining the angle of the detector to the direction of radiation source an angular calibration scale was applied on the phantom body (angle step 10°). Accumulated charges (nC) of the diodes (collecting time = 10 s) were measured with electrometer PTW VIVADOS in Multichannel Mode. GammaMed Plus remote afterloader with source Ir-192 (GM12000680, active dimensions 0.6 mm diameter and 3.5 mm height) was used. The 0.6 cc Farmer chamber type 30001, placed inside the adaptor 30001 on the opposite side of the phantom, was taken as a reference chamber.

**Results:** On the figure the measured detector readings (•) are presented together with data for previously studied rectum (x) detector T9112-01725 (fluoroscopic images of these catheters you can see at the middle part of the figure). The curves are normalized to 1.0 for lowest value of the readings. The diameter of bladder catheter (3 mm) is ~two times smaller than the diameter of rectum catheter (7 mm) and it might have been expected that the angular response of bladder detector is different. But measurements were shown a similar angular dependence of bladder and rectum diode readings. From measured curves it can be identified that angular component (A), which oscillates up to 5-6% of readings, and the 'off-axial' component (B), for this particular detector, is value of order 1%.